EGU25-3587, updated on 22 Apr 2026
https://doi.org/10.5194/egusphere-egu25-3587
EGU General Assembly 2025

Modelling the Climatic Impact of Hydrogen Emissions in SSP scenarios

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With a possible transition toward a hydrogen-based economy as an alternative to fossil fuels, concerns arise regarding the environmental impacts of hydrogen emissions. Although hydrogen has no direct radiative forcing, it indirectly contributes to global warming through its interactions with atmospheric components such as methane, ozone, and water vapor. This impact has not been assessed in the SSP scenarios or in the broader AR6 scenario database.

This study integrates a comprehensive hydrogen budget into the OSCAR compact Earth system model, focusing on its sources, sinks, and chemical interactions, to assess its potential climatic impacts under the main SSP scenarios of ScenarioMIP. We evaluated key anthropogenic sources such as fossil fuel combustion, biomass burning, and leakage from hydrogen infrastructure. We parameterised secondary sources such as methane and VOC oxidation. The major sinks, atmospheric oxidation by hydroxyl radicals and soil uptake by bacteria, were modelled using simplified equations calibrated against outputs from complex process-based models.

With our approach, the hydrogen and methane cycles are fully interacting during transient simulations. Our simulations quantify the influence of hydrogen emissions on methane lifetime, tropospheric ozone, and stratospheric water vapor, which combined amount to a slight increase in radiative forcing. Under a leakage rate of 1.8%, the global temperature impact remains minor, altering predictions by a few hundredths of a degree, while a higher leakage rate of 10% amplifies the effect but hardly reaches one tenth of a degree in any scenario. The quantitative impact of hydrogen emissions in terms of global temperature exhibits a widely differing profile across scenarios, strongly influenced by the IAMs' assumptions regarding future use of hydrogen and by the scenarios' own emissions of methane.

Although these estimates of the climatic impact of hydrogen are not entirely negligible, especially in low-warming scenarios for which every fraction of a degree counts, our findings suggest that correcting the absence of its quantification in the AR6 scenario database would not lead to a drastic reclassification of these scenarios, which should be reassuring for policy-makers.